

# FAILURE DETECTION METHOD AND APPARATUS FOR SENSOR NETWORK

## CROSS REFERENCE TO RELATED APPLICATION

This application is based on and incorporates herein by  
5 reference Japanese Patent Application No. 2001-67315 filed March  
9, 2001.

## FIELD OF THE INVENTION

The present invention relates to a failure detection method  
and apparatus for a sensor network where a plurality of pressure  
10 sensitive sensors are connected in a matrix.

## BACKGROUND OF THE INVENTION

In a passenger detection sensor network for a vehicle,  
condition of wiring that connects each pressure sensitive sensor  
to an electronic control unit (ECU) needs to be monitored for a  
proper passenger detection operation. One proposed method for  
15 monitoring the matrix sensor network is shown in Fig. 7. A line  
120 for monitoring row lines 100 by the ECU is connected to each  
row line 100 (#1 to #3), and a resistor 130 is connected between  
each row line 100 and its corresponding line 120. For monitoring  
20 column lines 110 (#A to #C), lines 120 and resistors 130 are  
connected in the same manner as rows. As a result, series circuits  
are constructed so that operativeness of lines 100 and 110 is  
monitored by feeding a test current by the ECU.

However, to detect failures (open and/or short) in a matrix  
25 circuit that contains m rows and n columns, a number of lines as  
many as  $m \times 2 + n \times 2$  are required even though a plurality of pressure  
sensitive sensors is connected in a matrix to reduce wiring.

## SUMMARY OF THE INVENTION

The present invention therefore has an objective to provide a failure detection method and apparatus for a sensor network requiring less wiring for a monitoring operation.

5           According to the present invention, a monitoring device such as a resistor is connected to ends of two row lines or two column lines to form a series circuit with a pull-up resistor. A voltage is applied to the series circuit to check operativeness of those lines based on the voltage or current variations in the series circuit. If no failure is present in the series circuit, the divided voltage corresponding to the ratio of the pull-up resistor and a sensor resistor is developed. If the series circuit is in the shorted condition, the voltage across the monitoring device is 0V. If the series circuit is in the open condition, the voltage is equal to the voltage applied to the series circuit.

## BRIEF DESCRIPTION OF THE DRAWINGS

The above and other objectives, features, and advantages of the present invention will become more apparent from the following detailed description made with reference to the accompanying drawings. In the drawings:

20           Fig. 1 is a circuit diagram showing a passenger detecting system having a sensor network to which monitoring resistors are connected;

25           Fig. 2 is a schematic diagram showing a sensor network to which monitoring resistors are connected in another way;

          Fig. 3 is a schematic diagram showing a sensor network to which monitoring resistors are connected in still another way;

Fig. 4 is a diagram showing a circuit condition during a passenger detecting operation;

Fig. 5 is a diagram showing a circuit condition during a failure detecting operation in row lines;

Fig. 6 is a diagram showing a circuit condition during a failure detecting operation in column lines; and

Fig. 7 is a schematic diagram showing a sensor network to which monitoring resistors are connected in a related art.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The preferred embodiments of the present invention will be explained with reference to various embodiments.

As shown in Fig. 1, a passenger detection system includes a sensor network 1 installed inside a vehicle seat (underneath a seating). The sensor network 1 has a plurality of pressure sensitive sensors R (R11-Rmn) connected between row lines 2a and column lines 2b. These pressure sensitive sensors R are connected in a matrix (m×n). One end of each row line 2a is connectable to an ECU 10 or ground via a multiplexer 3, so is one end of each column line 2b via a multiplexer 4. Each pressure sensitive sensor R has upper and lower electrodes printed on a film (not shown). These electrodes are connected to the lines 2a and 2b. When a load (pressure) is applied to the sensor R, a resistance between the electrodes varies as their contact area varies.

The multiplexers 3 and 4 are switches with three channels. It selects one pressure sensitive sensor R to be sensed by properly switching those channels under control of the ECU 10. A voltage Vcc is applied across the pressure sensitive sensor R through a

pull-up resistor  $R_p$ . The voltage  $V_{cc}$  is divided by the pressure sensitive sensor  $R$  and the pull-up resistor  $R_p$ . The divided voltage  $[R \times V_{cc} / (R + R_p)]$  is inputted into the ECU 10 as sensor information.

5 A buffer circuit 5 is connected between the ECU 10 and the multiplexers 3 and 4 in order to prevent a current flow into lines other than the lines used while a passenger detecting operation is performed by the ECU 10. The buffer circuit 5 is a voltage follower circuit including an operational amplifier. It is configured to output a voltage equal to a voltage across the pressure sensitive sensor  $R$  which is under passenger detecting operation. Thus, the system detects whether a passenger is seated or not, or whether a passenger is an adult or a child when the presence of a passenger is detected.

10 The system also has a failure detection function that detects a failure, open or short, in wiring 2 (row lines 2a and column lines 2b). Two of row lines 2a are connected to each other via a monitoring resistor  $R_d$  to form a series circuit for the failure detection function. The failure detection is a function for monitoring operativeness of the wiring 2 based on the voltage across the monitoring resistor  $R_d$ . In monitoring operation, one end of these two row lines 2a is connected to the resistor  $R_p$  and the other end is grounded by the multiplexer 3. A voltage is applied to the series circuit to check operativeness of the lines 2a based on the voltage across the resistor  $R_d$ . Operativeness of the column lines 2b is checked in the same manner as the row lines 2a.

25 As shown in Figs. 2 and 3, the monitoring resistors  $R_d$  may alternatively be connected between both ends of the two row lines

2a and two column lines 2b, respectively.

Next, operation of this embodiment is discussed.

[Passenger Detecting Operation]

It is assumed that a pressure sensitive sensor R11 connected  
5 between a row line 2a (#1) and a column line 2b (#A) is under  
passenger detecting operation. Channels of the multiplexers 3 and  
4 are switched as shown in Fig. 4 so that a current flows from the  
pull-up resistor Rp into the sensor R11 via the row line #1 and  
column line #A. The divided voltage  $[R11 \times Vcc / (R11 + Rp)]$  is inputted  
10 to the ECU 10 as information of the sensor R11, that is, as load  
applied to the sensor R11. Since the output voltage of the buffer  
circuit 5 is applied to the rest of lines 2a and 2b, from second  
row line #2 to the last row line #m and from the second column line  
#B to the last column line #n, no current flows to these lines.

15 [Failure Detection in Row Lines 2a]

When detecting a failure in the wiring 2 between the row lines  
#1 and #2, channels of the multiplexer 3 are switched as shown in  
Fig. 5. Therefore, ends of the row lines #1 and #2 are connected  
to the lower potential side of the pull-up resistor Rp and ground,  
20 respectively. Thus, the voltage Vcc is applied to feed a test  
current through the resistor Rp to the series circuit including  
the monitoring resistor Rd connected in series via the row lines  
#1 and #2. The same voltage is applied to the rest of the wiring  
via the buffer circuit 5 so that no current flows to the other wiring  
25 (other series circuits). A voltage across the resistor Rd is  
inputted to the ECU 10.

If the series circuit is in the shorted condition, the voltage

across the resistor  $R_d$  inputted to the ECU 10 is 0. If the circuit is in the open condition, the voltage inputted to the ECU 10 is equal to the voltage  $V_{cc}$  applied to the series circuit. If no failure is present in the series circuit, divided voltage  
5  $[R_d \times V_{cc} / (R_d + R_p)]$  is inputted to the ECU 10. The ECU 10 thus detects the operativeness of the row lines 2a in response to the voltage inputted thereto.

#### [Failure Detection in Column Lines 2b]

When detecting a failure in wiring between the column lines  
10 #A and #B, each channel of the multiplexer 4 is switched as shown in Fig. 6. Therefore, ends of the column lines #A and #B are connected to the lower potential side of the pull-up resistor  $R_p$  and ground, respectively. The series circuit where a voltage is applied to feed a test current has the resistors  $R_p$  and  $R_d$  connected  
15 in series via column lines #A and #B. The same voltage is applied to the rest of the wiring 2 via the buffer circuit 5 so that no current flows to the other wiring. The voltage across the resistor  $R_d$  is inputted to the ECU 10.

If the series circuit is in the shorted condition, the voltage  
20 across the resistor  $R_d$  inputted to the ECU 10 is 0. If the circuit is in the open condition, the voltage inputted to the ECU 10 is equal to the voltage  $V_{cc}$  applied to the series circuit. If no failure is present in the series circuit, the divided voltage  
25  $[R_d \times V_{cc} / (R_d + R_p)]$  is inputted to the ECU 10. The ECU 10 thus detects the operativeness of the column lines 2b in response to the voltage inputted thereto.

In this embodiment, the series circuit where the monitoring

resistor Rd is connected in series with the row lines 2a or the column lines 2b is formed. By feeding the test current to the series circuit, the voltage across the resistor Rd is monitored to detect a failure in the wiring 2. In other words, any failure in the sensor network 1 can be detected without additional wiring other than the row lines 2a and the column lines 2b connected to the sensors R.

Moreover, the size of detection circuit PCB need not be increased since no additional wiring for monitoring is required.

The present invention should not be limited to the embodiment previously discussed and shown in the figures, but may be implemented in various ways without departing from the spirit of the invention. For example, diodes or capacitors can be used as an alternative to the monitoring resistors Rd. The pull-up resistor Rp may be replaced with a resistor connected to the ground side. The sensor network 1 may be used for various purposes other than passenger detection.